Manufacturing Enterprise Engineering

Program Manager: Albert W Jones
Total FTE: 5.25
Total Funding: $1,200,000

Goal

Provide U.S. industry with standards and tools that facilitate the integration of high-level manufacturing business systems within and across enterprises.

Program Objectives

FY2000

Develop structured methods, guidelines, services, and standards to support collaboration technologies used in multi-enterprise operations.

Collaboratory Technologies

Develop structured methods, guidelines, services, and standards to support collaboration technologies used in multi-enterprise operations

FY2001

Deploy a complete suite of standards for Product Data Management (PDM) interfaces to other engineering tools and enterprise operations systems.

Product Data Management

Implement and test the Object Management Group (OMG) standard for Product Data Management interfaces in the Framework Test System (collaborating with the Information Technology Metrology for Manufacturing program).

FY2001

Develop standards for data models and interfaces for Manufacturing Execution Systems (MES), Enterprise Resource Planning (ERP), and supply chain management for the extended enterprise.

Manufacturing Execution System/Plant Integration

Develop information requirements for MES-to-plant integration.

FY2002

Put in place an architecture and an integrating infrastructure for the next generation of electronic commerce applications.

Business Process Integration

Develop activity models of supply chain operations needed for advanced planning and scheduling, supply chain management, and electronic commerce.

FY2003

Pilot a distributed integration testbed.

FY2005

Demonstrate self-integrating enterprise software systems.

Customer Needs

This program seeks to address the needs of four types of customers: (1) manufacturing firms that hope to deploy enterprise solutions, (2) consulting firms that provide systems integration services, (3) vendors that provide manufacturing software and information technology products, and (4) organizations that develop manufacturing standards, research, and analysis. The following synopses summarize the needs of these customers relative to this program.

Product Data Management (PDM) systems are becoming pervasive throughout manufacturing enterprises. Nearly 100 % of Fortune 500 companies and 80 % of manufacturers with business volume greater than $50 M use PDM. In addition, PDM is the software tool with the fastest growing in Small and Medium

Enterprises (SMEs), 28 % (Gartner Group). Nevertheless, no single vendor commands more than 20 % of the market. It is common for large manufacturers to have several different PDM systems in their enterprise that must share information. Furthermore, the increasing amount of contracted design and production has made "external" access to these PDMs an additional concern. All of this has led to a desire by users and, to some extent, by vendors, for PDM interface standards. Four, formal, PDM interface standards are being implemented by the six leading PDM vendors - ISO 10303-203, OMG PDM Enablers, Draft International Standard 10303-214, and the STEP (Standard for the Exchange of Product model data) PDM schema. This creates a need for harmonization in addition to conformance and interoperability testing. In addition, several specific needs that are not addressed by these standards highlight areas for additional standards development.

The $2.5 B ERP system purchases in 1999 is estimated to top $60 B by 2003 (AMR, Inc.). Two ERP vendors dominate the current market with about a 50 % share; but, there are six others with substantial market share (30 %) and about 40 smaller ERP providers. The philosophy of ERP is to integrate all enterprise activities into one large system with a cohesive transaction, data, and applications management system. Implementing this philosophy requires a large number of data model and interface standards. The notion that the top two vendors will create these de facto standards for the entire industry is not likely to be correct. Consequently, there is a need for international standards.

Revenues on "supply chain management" software have increased from $1.8 B in 1997 to $4.5 B in 1999 and are expected to exceed $18 B by 2003 (AMR). In the search for leanness and agility, supply chain partners are demanding a wide range of new, advanced software that performs coordinated planning across the entire supply chain. This new software will require different kinds of information exchange standards. The nominal standards for supply-chain exchanges, Electronic Data Interchange (EDI), are not standards in the usual sense. Rather, they are frameworks for information groups with specified data representations. Each pair of trading partners chooses the information sets they will exchange, their organization, and their meaning. The current sets are not sufficient to handle the information requirements needed to achieve this coordinated planning across the entire supply chain.

By 2003, it is estimated that 137 million business users will be involved in remote work of some kind (Gartner Group). In addition, the Internet is leading manufacturers to outsource what they do not consider their core competencies. Industry sources indicate that Fortune 500 companies already outsource 78 % of their transportation, 54 % of their distribution, and 46 % of their manufacturing. These numbers are expected to increase, with the third-party logistics industry expected to double to $50 B in the next two years (Technology Insights Alert). This means that electronic collaboration between individuals and Internet-based collaboration between trading partners will continue to increase in frequency and importance. While the number of collaboration software tools has been growing, there are no metrics for evaluating the effectiveness of the different types of tools. In addition, no attempts have been made to identify future standards requirements resulting from the use of information technology for collaboration.

Sales of Manufacturing Execution System (MES) software reached $218 M in 1998; they are expected to top $370 M by 2002 (Managing Automation). This growth has created a pressing need to transform and mine the data produced and sometimes maintained in shop floor scheduling, control, and data acquisition systems. Moreover, reduced life spans for new products have put new pressure on manufacturers to reconfigure their MES software environment more frequently and more rapidly. A typical systems environment is made up of products

from several vendors. The integration of these products is hampered by three problems. First, there is no standard set of functions for a given system type. For example, some MES systems contain their own scheduling component, others do not. Second, there is no common understanding, and hence no formal models, for the data that these systems share. For example, they all generate, use, and provide output data on factory resources. However, they all have a different view of those resources. Third, there are no standard interfaces among the systems themselves, or between these systems and higher-level systems in the enterprise.

Technical Approach

This program will provide standards solutions to solve current enterprise integration problems and it will examine evolving technology solutions in anticipation of future standards needs. It will base its work on sound scientific principles and strike a balance among research, testing, demonstrations, and standards participation. It will work to harmonize competing enterprise integration standards. It will operate against meaningful metrics and it will evaluate its efforts to assure relevancy to the aforementioned customer needs.

The program will produce four primary classes of products:

- Analyses documenting issues of concern to the manufacturing community regarding the adoption of leading-edge information infrastructure technologies.

- Models that represent the information, processes, structure, and behavior of manufacturing enterprise systems.

- Prototype systems that demonstrate feasibility of standards-based solutions as well as pre-standard technology solutions to manufacturing enterprise integration problems.

- Standards that document consensus agreements regarding terminology required to describe manufacturing enterprise systems, information required to operate enterprise systems, interface definitions required to integrate enterprise systems, and architectures required to specify the structure of extended enterprise systems.

A cornerstone of enterprise integration is the set of interface specifications that describe how information is transmitted into and out of software applications. The Manufacturing Engineering Laboratory's Manufacturing Systems Integration Division staff developed an interface specification for Product Data Management (PDM), which provided a basis for the development of the PDM Enablers interface standard under the auspices of the Object Management Group (OMG). This program conducts a large portion of the formal interface standardization within the OMG Manufacturing Domain Task Force. Informal specifications as well as the formal standards are often written in the Interface Definition Language (IDL). The program is considering an involvement in several other interface-definition efforts. They include: eXtensible Markup Language (XML)-based PDM exchanges between trading partners in a supply chain, standards for Product and Process data exchange with ERP, medium-grained PDM interfaces for engineering tools, and interfaces for a federation of PDM "agents". The program is also considering a role in the coordination of PDM/XML standards efforts (NEMI, DISA, ISO TC 184/SC4) and the development of conformance test suites for PDM Schema and PDM Enablers, among others.

Companies need to share technical, business, and administrative information both within their own organizations and with their trading partners. This program management holds the position that the development of many independent models of that information will not lead to integration across the extended enterprise or supply chain. Program staff will form partnerships with industry to create a

standards roadmap, which emphasizes both operations and planning concerns and which is based on the Supply Chain Operations Reference (SCOR) model of the business processes within the supply chain. It will form partnerships with university researchers to launch a research program - based on operations research, artificial intelligence, and simulation - to develop and test algorithms for advanced planning and scheduling. These algorithms will provide a foundation for the information models that will be the basis for the coordination across the supply chain. The program staff will also be involved in standards development and promulgation. The initial focus will be PDM-ERP interfaces; the more exploratory area involves the current EDI and related "electronic commerce" standards.

The Collaboration Technologies project utilizes expertise and leverages programs from other NIST units including the Information Technology Laboratory (ITL) and the Manufacturing Extension Partnership (MEP) Program in addition to multiple divisions within the Manufacturing Engineering Laboratory (MEL). MEL is providing the manufacturing design and process expertise, and research and program coordination. ITL is providing usability assessment, networking, and collaboration tool expertise. This includes the assessment and development of data visualization tools, tools to simulate network behavior for collaboration tool assessment, tools to view and play back multiple data streams indexed over time synchronously or a Computer-Aided Design (CAD) model in VRML (Virtual Reality Modeling Language), and the integration of state-of-the-art collaboration tools with existing software. Further expertise in evaluation of collaborative tools within manufacturing scenarios is provided by leveraging the Defense Advanced Research Projects Agency's (DARPA) Intelligent Collaboration and Visualization (ICV) program. MEP is providing a domain within which to implement and assess the use of collaboration

technologies to enable data dissemination and knowledge exchange for small and medium enterprises (SMEs). A significant cooperative agreement with the University of Michigan's Collaboratory for Research in Electronic Work (CREW) has just commenced that enriches the pool of expertise assessing the usefulness and usability of computer-supported cooperative work (CSCW) tools and their impact in the workplace.

MEL has a history of developing data models, architectures, and interfaces to support production systems. This program continues this tradition with its participation in three standards efforts related to MES. The first effort consists of interface development and functional definition activities within the Manufacturing Execution Systems and Machine Control working group within the Manufacturing Domain Task Force of the OMG - NIST co-chairs this group. The second effort consists of data model developments within ISO Technical Committee (TC) 184/Sub-committee (SC) 4/Working Group (WG) 8, known as MANDATE - Manufacturing Management Data. These models include a resource model, a time model, and a manufacturing flow model. The third effort includes terminology, object model, and functional description definition taking place in the Standards of Practice (SP95) activity on Enterprise/Control Integration of the International Society of Instrumentation and Control (ISA). This program's objectives plan on a high level of participation in these activities for the foreseeable future and to act as facilitator and coordinator between them.

The Manufacturing Enterprise Engineering program is working with its customers to develop an overarching architecture for engineering the integrated enterprises of tomorrow. This architecture provides a context for articulating the strategies, mission, and relationships between humans, machines, and information systems within a single enterprise and across multiple enterprises. This work is conducted through participation in the ISO

Working Group on Modeling and Architecture (ISO TC/184/SC5/WG1) and the IFAC/IFIP (International Federation of Automatic Control / International Federation for Information Processing) Task Force for Enterprise Integration. The program staff has contributed to the development of the Generalized Enterprise Reference Architecture and Methodologies (GERAM), Concepts and Rules for Enterprise Models (ISO 14258), Requirements for Enterprise Reference Architectures and Methodology (ISO 15704), and the Strategic Plan for the ISO Sub-committee on Architecture and Communications. The program staff hosts or co-hosts several workshops and conferences each year such as the Joint Workshop on Standards for the Use of Models that Define the Data and Processes of Information Systems (Joint Workshop), and the International Conference on Enterprise Integration Modeling Technology (ICEIMT).

Current views on the decomposition and behavior of manufacturing enterprise software are based on the belief that software is largely passive in its execution. Emerging views are based on the belief that some of these systems would exhibit increased fault tolerance and gains in operational efficiency if they were designed to operate as autonomously interacting agents. These characteristics will be critical in the emerging environment of electronic commerce. The program in Manufacturing Enterprise Engineering is examining the ramifications of enterprise adoption of this new paradigm for some manufacturing software systems. The program staff is working with the Software Engineering Institute at Carnegie Mellon University and a guest researcher from Oak Ridge National Labs to develop autonomous agent infrastructures and testbeds. Staff are also working with manufacturing firms funded by the NIST Small Business Innovative Research (SBIR) program and Advanced Technology Program (ATP) to carry out research on autonomous agent technologies, and organizations such as OMG and

Foundation for Intelligent Physical Agents (FIPA) that have special interest groups on agent technologies.

Standards Participation

- ANSI/ASC X12: The Accredited Standards Committee (ASC) X12 has been chartered by the (ANSI) to develop uniform standards for inter-industry electronic interchange of business transactions commonly known as electronic data interchange (EDI). MEL will continue to develop our understanding of X12 and track its progress.

- Foundation for Intelligent Physical Agents (FIPA), Geneva, Switzerland: FIPA is a quasi standards development organization. Their interest in software agents includes the manufacturing domain and, specifically, Manufacturing Execution Systems. The Framework project made initial contacts with FIPA in fiscal year 1998 and co-organized the first meeting of the Special Interest Group (SIG) on Product Design and Manufacturing at FIPA in 1999. (The Framework project was a project to establish a framework of standards and specifications for manufacturing software systems.)

- ISO TC184/SC4/WG8, MANDATE: MEL actively participates in the working group.

- ISO TC184/SC5/WG1 Enterprise Modeling Working Group: MEL chairs and actively participates in the working group.

- Object Management Group (OMG), Object Request Broker Operating System (ORBOS) and other ad hoc architecture working groups: MEL provides analysis and voting on architecture related activities. Occasional direct participation and written comment is provided in areas that directly affect potential manufacturing implementations.

- OMG Manufacturing Domain Task Force (MfgDTF): MEL participates in OMG's

Manufacturing Domain Task Force. This organization is responsible for setting the overarching strategy for the working groups that comprise the task force. Specific activities include:

- OMG MfgDTF, Product Data Management (PDM) Working Group - This working group is responsible for issuing Request for Information (RFI), Request for Proposals (RFP) and developing standards for PDM component interface definitions.

- OMG MfgDTF, Enterprise Resource Planning (ERP) Working Group - This working group is responsible for issuing RFIs, RFPs, and developing standards for ERP component interface definitions.

- OMG MfgDTF, Manufacturing Execution System/Machine Control (MES/MC) Working Group - This working group is responsible for issuing RFIs, RFPs, and developing standards for MES/MC component interface definitions.

- Open Applications Group: OAG is a consortium of enterprise applications software vendors (i.e., ERP vendors) who have created common standards for the integration of enterprise business applications. It produced the Open Applications Group Integration Specification (OAGIS), which is a requirements definition of information to be exchanged among ERP systems. MEL has found that the requirements specified in OAGIS are very relevant to the OMG ERP effort.

- UN/EDIFACT: The United Nations (UN) Electronic Data Interchange for Administration, Commerce, and Transportation (EDIFACT) is the international counterpart to X12. MEL will continue to develop our understanding of EDIFACT activities and track its progress.

- XML/EDI: XML may be the means to bridge EDI into Internet electronic commerce (EC) by making the existing EDI knowledge base more suitable to Internet EC developers. ASC X12 has joined CommerceNet and the XML/EDI Group in a joint project to investigate translating ASC X12 data elements, segments, and transactions into XML. MEL will continue to track the development of XML/EDI.

Accomplishments

- September FY1999 Developed a quality program to reduce the time significantly to develop and validate ISO TC184 SC4 standards.

- September FY1999 Participated in the development of an architecture that increases interoperability of the information model standards (Application Modules) developed in ISO TC184 SC4.

- September FY1999 Completed OMG RFP entitled Data Acquisition from Industrial Systems, which requests the specification of standard interfaces to enable plug-and-play interconnection of smart devices, machine controllers, and Supervisory Control and Data Acquisition (SCADA) systems with industrial information systems.

- September FY1999 Demonstrated the NIST Manufacturing Collaboratory at the Annual Welding Trade Show held in St. Louis, MO and the DOE2000 PI Retreat.

- September FY1999 Participated in two workshops to define the relationships between the OMG PDM Enablers standard and the emerging STEP PDM Schema standard.

- September FY1999 Designed and developed a prototype tool for viewing and annotating synchronized, multiple, multimedia data streams for better visualization of complex manufacturing processes.

- September FY1999 Initiated Economic Planning Study on Integrated Supply Chain Operations.

- September FY1999 Completed NIST's response to the RFI on MES, which had been issued by the OMG MfgDTF.

- October FY1999 Co-chaired workshop to improve harmonization of standards-development activities related to enterprise reference models, software engineering lifecycle management, and distributed application services

- September FY1998 Developed a white paper for the OMG that defined the Machine Control area and identified potential classes of related, standardized interfaces.

- January FY1998 Developed models identifying activities and information flows for electronic commerce, supply chain operations, ERP, and MES.

- December FY1998 Developed ISO 14258 and 15704 standards for enterprise representation and modeling.

- December FY1998 Actively participated in initial drafting through adoption of the Product Data Management Enablers interface standard by OMG.

- December FY1998 Participated in the development of an architecture that increases the interoperability of the information model standards (Application Modules) developed in ISO TC184 SC4.

- December FY1997 Hosted five enterprise integration workshops and the International Conference on Enterprise Integration Modeling and Technology - ICEIMT97.